OZARKIAN FRESH-WATER MUSSELS (UNIONOIDEA) IN THE UPPER ELEVEN POINT RIVER, MISSOURI

ROBERT E. WARREN
ILLINOIS STATE MUSEUM
CORNER SPRING AND EDWARDS
SPRINGFIELD, ILLINOIS 62706, U. S. A.

ABSTRACT

Fourteen species of fresh-water mussels (Bivalvia: Unionoidea) were collected in 1990 from the upper reaches of the Eleven Point River in Oregon County, Missouri. The collections constitute range extensions for all 14 species, including five species newly recorded for the Eleven Point River in Missouri and nine upstream records for species previously documented in the Missouri section of the river. The collections are dominated by four endemic Ozarkian species [*Fusconaia ozarkensis* (Call), *Lampsilis reeviana brevicula* (Call), *Venustaconcha pleasi* (Marsh), and *Ptychobranchus occidentalis* (Conrad)], two of which are rare/uncommon in Missouri. There is significant variation in species composition along the 26 km section of river studied, which could be related to the inflow of numerous springs and a considerable downstream increase in stream discharge. The upper Eleven Point River may be a suitable refuge for the conservation of Ozarkian mussel communities.

The Interior Highlands region of southern Missouri, northern Arkansas, and eastern Oklahoma is an isolated upland comprised of two rugged physiographic provinces, the Ozark Plateau and the Ouachita Mountains. Streams draining this area are inhabited by many species of aquatic organisms that live nowhere else. The list of endemic taxa includes at least 14 species of fish (Pflieger, 1975), seven gastropods (Gordon, 1980), and nine species of fresh-water mussels (cf. Gordon, 1980; Johnson, 1980; Oesch, 1984).

Many mussel species endemic to the Interior Highlands are adapted to the clear, high-gradient streams with coarse bed material that are typical of the region's drainages (see Oesch, 1984; Warren, 1991). Because of their rather limited habitat tolerances, these mussels can be highly susceptible to the effects of recent ecological changes stemming from pollution, excess siltation, and the damming of streams. The threat to these species is underscored by the fact that there are clear parallels between the Ozarkian faunal province of the Interior Highlands and the Cumberlandian faunal province of the Cumberland Plateau region of eastern Kentucky and Tennessee (van der Schalie and van der Schalie, 1950). Several of the endemic Ozarkian mussel species have closely related counterparts in the Cumberland region. These pairs of species share not only a common ancestry [e.g. *Fusconaia ozarkansis* (Call) and *F. barnesiana* (Lea); see Johnson, 1980; Ortmann, 1917], but also a preference for clear, energetic streams with coarse bed materials. This parallel is important because the Cumberlandian mussel fauna has been depleted or destroyed in many areas due to the effects of modern development (Bogan and Parmalee, 1983; Isom, 1969; Stansbery, 1970, 1971). The Ozarkian fauna is susceptible to the same fate, and a majority of its endemic taxa have already appeared on lists of rare and endangered species (see Harris and Gordon, 1987; Nordstrom *et al.*, 1977; Oesch, 1984).

To expand on a recent statement by Harris and Gordon (1987:54), there is an urgent need to better delineate the distribution and biology of fresh-water mussels throughout the Interior Highlands region, especially for endemic Ozarkian taxa with restricted environmental tolerances. This paper reports a preliminary survey of Unionacea in the upper Eleven Point River (White River Basin) in Oregon County, Missouri. Previous work in the White River Basin includes incidental remarks by Call (1895) and Utterback (1915-1916) in their statewide synopses of the mussels of Arkansas and Missouri, respectively. Zoogeographic studies include general surveys by Utterback (1917), Johnson (1980), and Gordon *et al.* (1980), which provide lists of taxa at the scale of the drainage basin. Oesch (1984) maps specific data on species locations for the central section of the Eleven Point River in Missouri, but his coverage does not extend into the upper reaches of the river.

The main objectives of the present study are to (1) document extant populations of mussel species in a 26 km stretch of the upper Eleven Point River, and (2) describe the composition and geographical variation of mussel communities in this area. The data have important implications

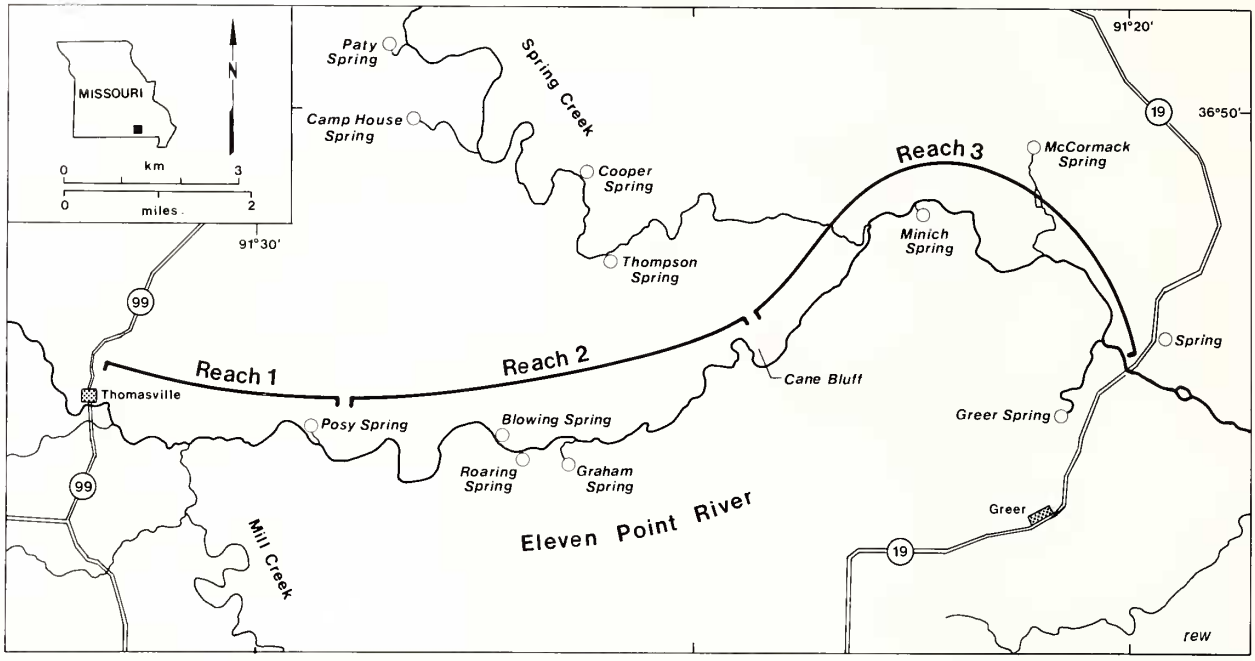

Fig. 1. Map of collection areas (Reaches 1-3) along the upper Eleven Point River in Oregon County, Missouri.

for the conservation of rare and potentially endangered Ozarkian species.

MATERIALS AND METHODS

The Eleven Point River is a clear, spring-fed Ozark stream. Its headwaters are in Howell County, Missouri, near the town of Willow Springs. The river flows southeastward across the Salem Plateau for about 241 km before joining the Spring River, a tributary of the Black River (White River Basin), in Randolph County, Arkansas (see Johnson and Beadles, 1977). The Eleven Point River flows through a steeply dissected karst landscape. Its flood plain is often narrow, and bluffs of Ordovician dolomite and sandstone tower up to 129 m above the valley floor (see Bretz, 1965).

The Eleven Point Basin is mainly an agricultural area today, with pastures on the high plateaus and low flood plains, and oak-hickory forest on the intervening slopes. Farms were established along the river as early as 1819, but population density remained low until well after the Civil War (Sauer, 1920). Logging became an important industry during the last quarter of the 19th century, reaching its peak about 1900 and declining thereafter. Deforestation probably increased rates of hillslope erosion in the area, but its historical impact on the water quality and geomorphology of the Eleven Point River is unknown.

The study area is a 26.4 km stretch of the Eleven Point River that runs downstream from Thomasville (State Highway 99) to the State Highway 19 bridge northeast of Greer (Fig. 1). This area comprises the upper reaches of the Eleven Point National Wild and Scenic River, which was established in 1968 and is maintained by the Mark Twain National Forest. Stream elevation drops from about 189.6 to 158.2 m AMSL in this area, and its gradient is relatively steep (1.2 m/km). The stream channel consists of a series of shallow riffles, raceways, and deeper pools. Its current velocity varies from slow to swift, and its substrate consists primarily of cobbles, gravel, and some sand.

Seven major springs enter the river in the study area, increasing its discharge considerably between Thomasville and the Highway 19 bridge. Greer Spring, the second largest spring in Missouri (Vineyard and Feder, 1974), enters the Eleven Point River 0.6 km upstream from the Highway 19 bridge, where it reportedly triples the discharge of the stream. The spring had an average discharge of 9.55 m^3/sec during its 68-year period of record (1922-1988; data from U. S. Geological Survey, Rolla). Discharge data are not available for the Eleven Point River above Greer Spring, although at Bardley, Missouri, 26 km downstream from Greer, its discharge averaged 21.66 m^3/sec during the 1922-1988 period of record (data from U. S. Geological Survey, Rolla).

The downstream increase in discharge has a perceptible effect on the river channel (Fig. 2), and could in turn be related to variation in mussel habitat. Between the upper and lower ends of the study area, channel width increases from about 10 to 22 m, channel depth increases from about 45 to >93 cm, and current velocity increases from moderate or swift to very swift. (Channel dimensions were measured at raceways.) There could also be a downstream change in substratum composition, but this has not been measured.

All mussels and mussel shells were collected by hand from gravel bars, riffles, and shallow areas along deeper raceways and pools (9-10 June 1990). The collection is a "grab" sample that was not obtained using quantitative sampl-

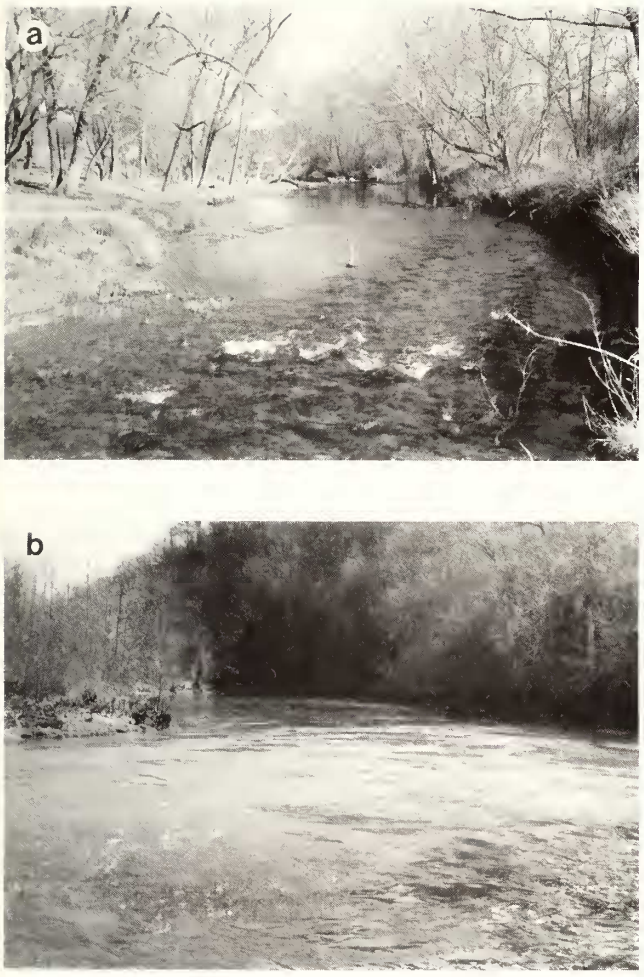

Fig. 2. Two views of the Eleven Point River, Oregon County, Missouri, showing (a) the relatively small channel at the upper end of Reach 1, looking downstream from below the Highway 99 bridge near Thomasville, and (b) the larger spring-fed channel at the lower end of Reach 3, looking downstream from below the Highway 19 bridge near Greer (February, 1991).

ing techniques (cf. Miller and Payne, 1988). The sample is presumably representative of the relative abundance of various species, but it is not appropriate for estimating the size, density, or demographic characteristics of local mussel populations.

Most of the specimens collected were dead. Some could have been residues of muskrat predation, but many appear to have died when they were dislodged by flood waters and displaced outside of the river channel, where they perished after the river returned to its banks. Water levels in the river were about 23-25 cm higher than normal at the time of our survey because of unusually heavy spring rainfall, but the water levels were receding.

Live individuals were collected as one sample and stored on ice. Dead individuals were collected from three separate reaches of the river (Fig. 1), cleaned, and stored dry. Reach 1, the farthest upstream, is 5.6 km long and runs from the Thomasville acess to a point below Posy Spring (0-5.6 km below Thomasville). Reach 2 is 9.4 km long and runs from the Posy Spring locality to the Cane Bluff access (5.6-15.0 km below Thomasville). Reach 3 runs 11.4 km from Cane Bluff to the Highway 19 bridge (15.0-26.4 km below Thomasville).

Dead shells were classified by valve condition. 'Fresh shells' are specimens with the nacre and periostracum intact and well-preserved. This category includes all paired valves that were still joined at the dorsal ligament. 'Eroded shells' have weathered, worn, or poorly preserved nacre and periostracum. Some broken shells were included in this category, but all retain the dorsal hinge line and are at least half complete.

Specimens were identified using a comparative collection at the Illinois State Museum, Springfield. Nomenclature follows Turgeon *et al.* (1988). All specimens are being curated at the Illinois State Museum.

RESULTS

Our collections in the upper Eleven Point River produced a total of 14 species of Unionacea (Table 1). All are represented by live or fresh-dead individuals. Nine species are upstream records for taxa previously documented by Oesch (1984) at or below the Highway 19 bridge in Missouri, including *Elliptio dilatata* (Rafinesque), *Fusconaia ozarkensis*, *Pleurobema coccineum* (Conrad), *Lampsilis cardium*

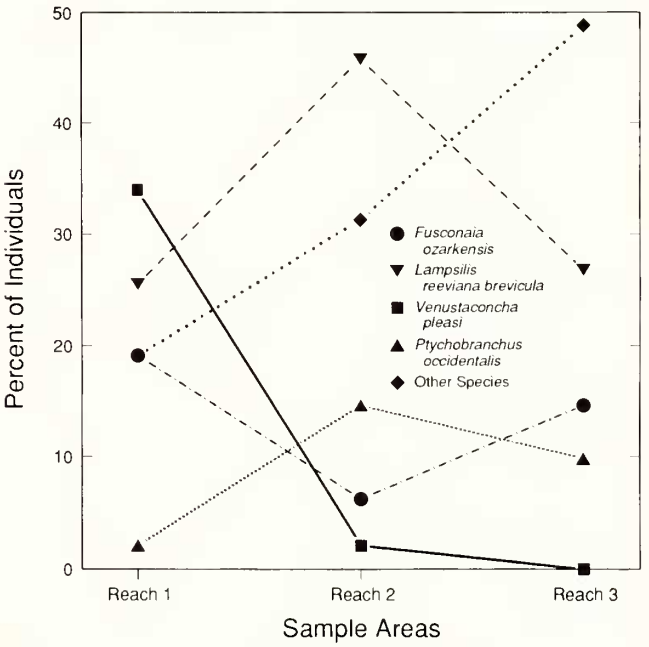

Fig. 3. Variation in the species composition of fresh-water mussels in three reaches of the upper Eleven Point River, Missouri. The four Ozarkian species in the collection *(Fusconaia ozarkensis, Lampsilis reeviana brevicula, Venustaconcha pleasi,* and *Ptychobranchus occidentalis)* are plotted individually. All 10 of the other taxa in the collection are Mississippian species.

Table 1. Fresh-water mussels from the Upper Eleven Point River, Oregon County, Missouri.

Taxon[1]	Live mussels	Dead mussels										
		Reach 1			Reach 2			Reach 3				
		Fresh	Eroded	Total	Fresh	Eroded	Total	Fresh	Eroded	Total	Total	Percent Total
Anodonta imbecillis Say, 1829	0	0	0	0	1	0	1	0	0	0	1	.6
Lasmigona costata (Rafinesque, 1820)	1	0	0	0	2	0	2	4	1	5	8	5.2
Strophitus undulatus (Say, 1817)	1	2	0	2	0	0	0	0	0	0	3	1.9
Elliptio dilatata (Rafinesque, 1820)	0	0	0	0	0	0	0	4	1	5	5	3.2
Fusconaia flava (Rafinesque, 1820)	0	0	0	0	2	0	2	0	0	0	2	1.3
F. ozarkensis (Call, 1887)	5	8	1	9	2	1	3	5	1	6	23	14.8
Pleurobema coccineum (Conrad, 1834)	1	0	0	0	0	1	1	3	2	5	7	4.5
Lampsilis cardium (Rafinesque, 1820)	0	2	0	2	5	2	7	1	1	2	11	7.1
L. reeviana brevicula (Call, 1887)	4	9	3	12	19	3	22	9	2	11	49	31.6
L. siliquoidea (Barnes, 1823)	0	0	0	0	1	1	2	1	1	2	4	2.6
Venustaconcha pleasi (Marsh, 1891)	5	15	1	16	1	0	1	0	0	0	22	14.2
Villosa iris (Lea, 1829)	0	2	1	3	0	0	0	1	0	1	4	2.6
V. lienosa (Conrad, 1834)	0	2	0	2	0	0	0	0	0	0	2	1.3
Ptychobranchus occidentalis (Conrad, 1836)	2	0	1	1	5	2	7	4	0	4	14	9.0
Number of individuals	19	40	7	47	38	10	48	32	9	41	155	99.9
Number of taxa	7	7	5	8	9	6	10	9	7	9	14	—

[1]Nomenclature follows Turgeon *et al.* (1988). Taxonomic ordering is phylogenetic above the genus level (after Davis and Fuller 1981:246).

(Rafinesque), *L. reeviana brevicula* (Call), *Venustaconcha pleasi* (Marsh), *Villosa iris* (Lea), *V. lienosa* (Conrad), and *Ptychobranchus occidentalis* (Conrad). Johnson (1980:133) lists an additional location for *L. r. brevicula* (as *V. reeviana*) at Riverton. Of the live individuals in our collection, two *F. ozarkensis* and three *V. pleasi* were gravid females.

Only two species documented by Oesch (1984) in the Eleven Point River are missing from our collections: *Cyclonaias tuberculata* (Rafinesque) and *Ligumia recta* (Lamarck). Oesch found *C. tuberculata* near the Highway 19 bridge, and recorded both species downstream near the Missouri-Arkansas border at Billmore, Missouri (Oesch 1984:117, 197). Their absence in our collections could be due to sampling error, limited zoogeographic ranges, or both.

The five remaining taxa are new records for the Eleven Point River in Missouri. These species include *Anodonta imbecillis* Say, *Lasmigona costata* (Rafinesque), *Strophitus undulatus* (Say), *Fusconaia flava* (Rafinesque), and *Lampsilis siliquoidea* (Barnes). All of these species have been documented elsewhere in the Black River Basin of southern Missouri and northern Arkansas (Gordon *et al.*, 1984; Oesch, 1984; Utterback, 1917), and it was not surprising to find them in the upper Eleven Point River. *Corbicula fluminea* (Müller), the intrusive Asian clam, was noted in all three reaches but was not collected.

There is a significant correlation between the species counts of live and dead individuals in the collection (Pearson's $r = .73$; $df = 12$; $p < .01$; see Rock, 1988:168). This test indicates that the two samples are proportionately representative of the same population. Nevertheless, large quantitative collections from stratified sample areas would undoubtedly provide more reliable data on the species composition of extant communities.

Judging from the relative frequencies of individuals in the collection, the mussel community in the upper Eleven Point River is dominated by four species. All are endemic Ozarkian taxa (Gordon, 1980; Johnson, 1980), and together they comprise 69.6% of the collection. In decreasing order of abundance, these are *Lampsilis r. brevicula* (31.6%), *Fusconaia ozarkensis* (14.8%), *Venustaconcha pleasi* (14.2%),

Table 2. Geographical variation in the species composition and diversity of fresh-water mussel communities along the Upper Eleven Point River in Oregon County, Missouri.

Variable	Reach 1	Reach 2	Reach 3
Leading dominant	*Venustaconcha pleasi*	*Lampsilis reeviana brevicula*	*Lampsilis reeviana brevicula*
Species (*S*)	8	10	9
Individuals (*N*)	47	48	41
Percent Ozarkian species (%*S*)[1]	50.0	40.0	33.3
Percent Ozarkian individuals (%*N*)[1]	80.9	68.7	51.2
Simpson index of species dominance (*D*)	.21	.25	.13
Shannon index of species richness (*H'*)	1.69	1.73	2.02

[1] Ozarkian species represented in the collection include *Fusconaia ozarkensis, Lampsilis reeviana brevicula, Venustaconcha pleasi,* and *Ptychobranchus occidentalis* (cf. Gordon 1980; Johnson 1980).

and *Ptychobranchus occidentalis* (9.0%). The remaining species are members of the Mississippian faunal province and have extensive ranges in the Mississippi River basin (Johnson, 1980; Oesch, 1984).

There is significant geographical variation in the species composition of dead shells collected from the three sample reaches (Tables 1-2; Fig. 3). The three leading dominants in Reach 1, the upstream section, are *Venustaconcha pleasi* (34.0%), *Lampsilis r. brevicula* (25.5%), and *Fusconaia ozarkensis* (19.1%). In Reach 2 there is a substantial drop in the abundance of *V. pleasi* (2.1%). The leading dominant in Reach 2 is *L. r. brevicula* (45.8%), followed by *Ptychobranchus occidentalis* (14.6%) and *L. cardium* (14.6%). *L. r. brevicula* is also the leading dominant in Reach 3, the downstream section, although its relative abundance drops to only 26.8%. The second leading dominant in Reach 3 is *F. ozarkensis* (14.6%), followed by *L. costata, Elliptio dilatata,* and *P. coccineum* at 12.2% each.

Geographical variation in species composition is accompanied by substantial downstream decreases in the relative abundance of Ozarkian elements and corresponding increases in Mississippian elements (Table 2; Fig. 3). Ozarkian taxa comprise 50% of the species documented in Reach 1, 40% in Reach 2, and 33% of the species in Reach 3. There is a parallel decline in the relative abundance of Ozarkian individuals, although the curve is even steeper. Ozarkian species account for more than 80% of individuals in Reach 1, but only about 69% in Reach 2 and 51% in Reach 3. These trends could reflect either a downstream decrease in the density of Ozarkian species, an upstream decrease in the density of Mississippian taxa, or both.

There also appears to be geographical variation in species diversity (Table 2). Although the numbers of species (*S*) and individuals (*N*) are fairly constant among reaches, there are discernible patterns in indexes of species dominance and species richness. The Simpson index (*D*; Simpson, 1949)—a measure of dominance concentration that correlates inversely with the evenness of species proportions—peaks in Reach 2 and is lowest in Reach 1. This pattern reflects the unusually high relative abundance of *Lampsilis r. brevicula* in Reach 2 and the relatively uniform proportions of various taxa in Reach 3. The Shannon index (*H'*; Shannon and Weaver, 1949)—a measure of species richness (see Magurran, 1988)—increases monotonically downstream from Reach 1 to Reach 3. This trend indicates that species diversity is relatively low in upstream areas dominated by Ozarkian taxa, but increases downstream where Mississippian taxa are relatively abundant. It should be cautioned that these patterns are based on rather limited data, and additional fieldwork is needed to confirm their validity.

DISCUSSION AND CONCLUSIONS

In a discussion of the prospects of rare and endangered fresh-water mussels in Arkansas, Harris and Gordon (1987) suggest that certain sections of the Eleven Point River and several other streams may offer suitable habitat for sustaining endangered species. However, in an assessment of the remaining habitat available to *Venustaconcha pleasi,* Oesch (1984:153) remarks that most of the Eleven Point River offers only "marginal habitat" because of its many tributary springs. Oesch (1984:229) suggests elsewhere that water from large springs is too cold and nutrient-poor for the survival of most mussel species. In a similar vein, Buchanan (1984:85) states that cold springs tend to reduce the abundance and species diversity of mussels in the Current River basin, the next drainage east of the Eleven Point Basin.

Despite these suggestions, our collections indicate there is a significant community of mussels in the upper reaches of the Eleven Point River, where spring water accounts for much of the river's discharge. It is true that the total number of known species (14) is low in comparison with the

Spring River, Black River, and other large streams in the White River Basin (see Gordon, 1982; Gordon *et al.*, 1984; Utterback, 1917). However, the Eleven Point River apparently provides suitable habitat for four endemic Ozarkian species *(Fusconaia ozarkensis, Lampsilis r. brevicula, Venustaconcha pleasi, Ptychobranchus occidentalis)*, which together comprise almost 70% of the individuals collected. Moreover, three of these species have appeared on state or national lists of rare and endangered fresh-water mussels (*F. ozarkensis* [Nordstrom *et al.*, 1977]; *V. pleasi* [Nordstrom *et al.*, 1977]; *P. occidentalis* [Stansbery, 1971]). None is currently on federal or state lists of protected species (Fish and Wildlife Service, 1989; Missouri Department of Conservation, 1986), but *F. ozarkensis* and *V. pleasi* are rare/uncommon in Missouri (Dennis Figg, pers. comm., 1990).

There is significant downstream variation in species composition in the study area, which could be related to the inflow of numerous springs and a considerable increase in stream discharge. The abundance of *Venustaconcha pleasi* in the upstream sample area (Reach 1) suggests it is primarily a headwater species that could be most common in the upper reaches of Ozark streams (Fig. 3). Spatial patterning in the relative abundance of *V. pleasi* has not been documented elsewhere, but our observations are consistent with Gordon's (1982) qualitative study of the White River in Arkansas, where *V. pleasi* is restricted to the upper reaches of the stream above Fayetteville. *Lampsilis r. brevicula* is the most abundant species in the middle and lower sample areas (Reaches 2-3), where most of the tributary springs enter the river. This correlation is consistent with Oesch's (1984:229) suggestion that the various subspecies of *L. reeviana* are unusually tolerant of streams below the outlets of major springs. *Fusconaia ozarkensis* has a bimodal pattern of abundance, with peaks in the upper and lower sample areas (Reaches 1 & 3), while *Ptychobranchus occidentalis* parallels the distribution of *L. r. brevicula* with a peak in the middle sample area (Reach 2). Considering the rather small samples of *F. ozarkensis* and *P. occidentalis*, the significance of their compositional patterns is questionable. Other taxa, all of which are Mississippian species, tend to increase monotonically downstream.

There is a downstream increase in species diversity in the study area that correlates inversely with downstream decreases in the qualitative and apparent quantitative abundance of Ozarkian taxa and individuals. The Ozarkian decline could reflect increased competition with Mississippian faunal elements in the lower reaches of the river, although quantitative collections are needed to test this possibility.

The upper Eleven Point River in Oregon County, Missouri, is a potential refuge for the conservation of Ozarkian mussel communities. Further research is needed to measure the size, density, and demographic structure of mussel populations in this area, as well as to assess their habitat tolerances and reproductive systems in greater detail. The section of river discussed here is currently being protected in accordance with the National Wild and Scenic Rivers Act, and it appears to provide appropriate habitat for fostering the survival of rare Ozarkian species.

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LITERATURE CITED

Bogan, A. E. and P. W. Parmalee. 1983. *Tennessee's Rare Wildlife, Volume II: The Mollusks.* Tennessee Wildlife Resources Agency, Nashville. 123 pp.

Bretz, J. H. 1965. *Geomorphic History of the Ozarks of Missouri.* Missouri Geological Survey and Water Resources, Rolla.

Buchanan, A. C. 1984. Naiades of the Current River Basin, Missouri. *American Malacological Bulletin* 2:85.

Call, R. E. 1895. A study of the Unionidae of Arkansas, with incidental reference to their distribution in the Mississippi Valley. *Transactions of the Academy of Science of St. Louis* 7:1-65.

Davis, G. M. and S. L. H. Fuller. 1981. Genetic relationships among recent Unionacea (Bivalvia) of North America. *Malacologia* 20:217-253.

Fish and Wildlife Service. 1989. Endangered and threatened wildlife and plants; animal notice of review. *Federal Register* 54(4):553-579.

Gordon, M. E. 1980. Recent Mollusca of Arkansas with annotations to systematics and zoogeography. *Proceedings of the Arkansas Academy of Science* 34:58-62.

Gordon, M. E. 1982. Mollusca of the White River, Arkansas and Missouri. *Southwestern Naturalist* 27:347-352.

Gordon, M. E., P. A. Durkee, H. M. Runke, and H. J. Zimmerman. 1984. *Mussel Fauna of the Black and Spring Rivers in Northeastern Arkansas.* Report to U. S. Army Corps of Engineers, Little Rock. 27 pp.

Gordon, M. E., L. R. Kraemer, and A. V. Brown. 1980. Unionacea of Arkansas: historical review, checklist, and observations on distributional patterns. *Bulletin of the American Malacological Union* 1979:31-37.

Harris, J. L. and M. E. Gordon. 1987. Distribution and status of rare and endangered mussels (Mollusca: Margaritiferidae, Unionidae) in Arkansas. *Proceedings of the Arkansas Academy of Science* 41:49-56.

Isom, B. G. 1969. The mussel resource of the Tennessee River. *Malacologia* 7:397-425.

Johnson, B. M. and J. K. Beadles. 1977. Fishes of the Eleven Point River within Arkansas. *Proceedings of the Arkansas Academy of Science* 31:58-61.

Johnson, R. I. 1980. Zoogeography of North American Unionacea (Mollusca: Bivalvia) north of the maximum Pleistocene glaciation. *Bulletin of the Museum of Comparative Zoology* 149:77-189.

Magurran, A. E. 1988. *Ecological Diversity and Its Measurement.* Princeton University Press, Princeton. 179 pp.

Miller, A. C. and B. S. Payne. 1988. The need for quantitative sampling to characterize size demography and density of freshwater mussel communities. *American Malacological Bulletin* 6:49-54.

Missouri Department of Conservation. 1986. *Checklist of Rare and*

Endangered Species of Missouri. Missouri Department of Conservation, Jefferson City. 20 pp.

Nordstrom, G. R., W. L. Pflieger, K. C. Sadler, and Walter H. Lewis. 1977. *Rare and Endangered Species of Missouri.* Missouri Department of Conservation and USDA Soil Conservation Service, Jefferson City, Missouri. 129 pp.

Oesch, R. D. 1984. *Missouri Naiades: A Guide to the Mussels of Missouri.* Missouri Department of Conservation, Jefferson City. 270 pp.

Ortmann, A. E. 1917. A new type of the nayad-genus Fusconaia. Group of F. Barnesiana Lea. *Nautilus* 31:58-64.

Pflieger, W. L. 1975. *The Fishes of Missouri.* Missouri Department of Conservation, Jefferson City. 343 pp.

Rock, N. M. S. 1988. *Numerical Geology.* Springer-Verlag, Berlin.

Sauer, C. O. 1920. *The Geography of the Ozark Highland of Missouri.* University of Chicago Press, Chicago. 245 pp.

Shannon, C. E. and W. Weaver. 1949. *The Mathematical Theory of Communication.* University of Illinois Press, Urbana. 125 pp.

Simpson, E. H. 1949. Measurement of diversity. *Nature* 163:688.

Stansbery, D. H. 1970. Eastern freshwater mollusks (I): the Mississippi and St. Lawrence River systems. *Malacologia* 10:9-22.

Stansbery, D. H. 1971. Rare and endangered freshwater mollusks in eastern United States. *In: Proceedings of a Symposium on Rare and Endangered Mollusks (Naiads) of the U. S.*, S. E. Jorgensen and R. W. Sharp, eds. pp. 5-18f. Ohio State University, Columbus.

Turgeon, D. D., A. E. Bogan, E. V. Coan, W. K. Emerson, W. G. Lyons, W. L. Pratt, C. F. E. Roper, A. Scheltema, F. G. Thompson, and J. D. Williams. 1988. *Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Mollusks.* Special Publication 16. American Fisheries Society, Bethesda, Maryland. 277 pp.

Utterback, W. I. 1915-1916. The naiades of Missouri. *American Midland Naturalist* 4:41-53, 97-152, 181-204, 244-273, 311-327, 339-354, 387-400, 432-464.

Utterback, W. I. 1917. Naiadgeography of Missouri. *American Midland Naturalist* 5:26-30.

van der Schalie, H. and A. van der Schalie. 1950. The mussels of the Mississippi River. *American Midland Naturalist* 44:448-466.

Vineyard, J. D. and G. L. Feder. 1974. *Springs of Missouri.* Missouri Geological Survey and Water Resources, Rolla, Missouri. 266 pp.

Warren, R. E. 1991. Fresh-water mussels as paleoenvironmental indicators: a quantitative approach to assemblage analysis. *In: Beamers, Bobwhites, and Blue-Points: Tributes to the Career of Paul W. Parmalee.* J. R. Purdue, W. E. Klippel, and B. W. Styles, eds. Illinois State Museum (in press).

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